This project has received funding from the European Union's Horizon 2020 Research and Innovation programme under GA No 101004730.

Task 7.4:
Very high gradient RF Guns operating in the C-band RF technology

4-5-2021 IFAST Kick-off Meeting

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IFAST

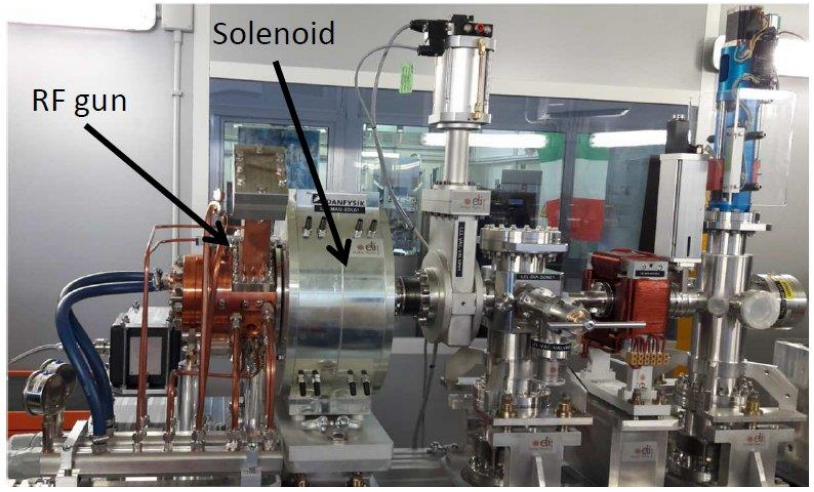
GOALS OF TASK 7.4

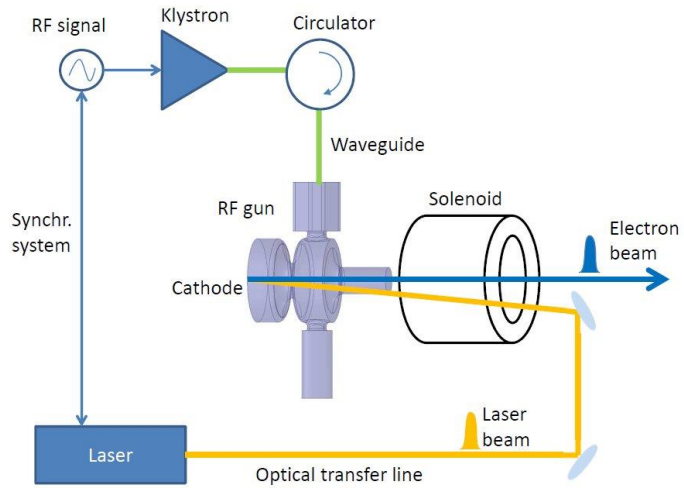
- **Research Institutions** involved: **INFN** (IT), **PSI** (SW);
- **Private Companies** involved: **VLD** (NE), **COMEB** (IT)
- **Design, realization and high power test of two different C-band (5.712 GHz) RF electron guns** operating at very high gradient cathode peak field (>160 MV/m): a Standing Wave (**SW**) gun and a Travelling Wave (**TW**) gun.
- **Comparison** of the performances.
- **Beam dynamics** simulations to exploit the device potentialities

D7.4 (M38): Mechanical realization and low power RF test of the two RF guns

RF PHOTO-GUNS

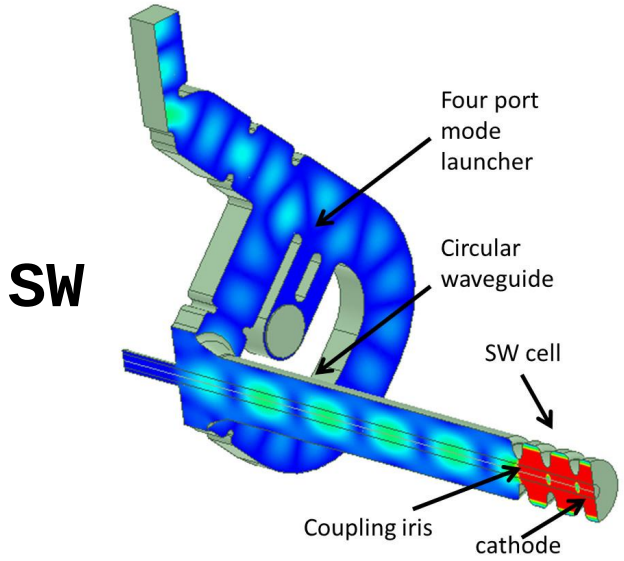
- **Photo-injectors** are widely used in modern facilities, especially in **FEL radiation source**, as very low-emittance and high-brightness electron sources.
- A **laser pulse** extracts the electrons from a cathode and an external **RF power source** excites the cavity accelerating mode so that the photo-electrons are immediately accelerated
- Presently, the **RF technology mostly used for RF Guns is the L or S-band** (f=1.3 or 3 GHz).
- According to **beam dynamics studies**, the higher the **peak electric field on the cathode**, the better the quality of the beam emerging from the Gun. In this respect the S-band represents the state-of-the-art, providing typical peak fields of **≈120 MV/m** on the cathode.

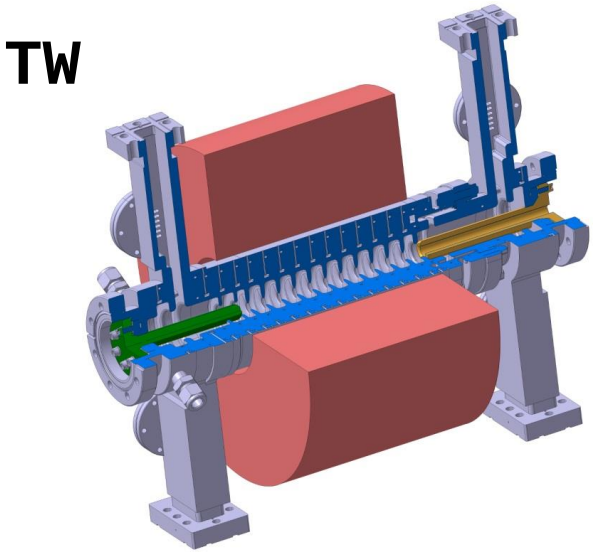




VERY HIGH GRADIENT C BAND GUNS: MOTIVATION

- The **C-band RF (f=5712 MHz) is a more recent technology** whose reliability have been already fully demonstrated (SwissFEL, SACLA).
- The frequency step-up from S-band to C-band can provide an improvement of the beam quality because of **higher achievable cathode peak field as high as 160-180 MV/m**.
- Because of its higher efficiency a C-band RF Gun is also suitable for **application requiring repetition rates in the 100 Hz÷1 kHz range**.
- The availability of a new state-of-the-art, compact and cost effective electron injector would **bring benefits to a large accelerator user community, primarily to the facilities at the frontiers of the beam quality such as FEL radiation sources, Thomson/Compton photon sources and plasma based accelerators**





MAIN RESPONSABILITIES

- **INFN**: coordination, **design** and low power test **SW Gun**, **solenoid** design and procurement, **design of the module** to test the gun, providing the **RF circulator**.

- **PSI: design, assembly, brazing** and low-power characterization of the **TW Gun**, hosting and setting up the **high-power test**.

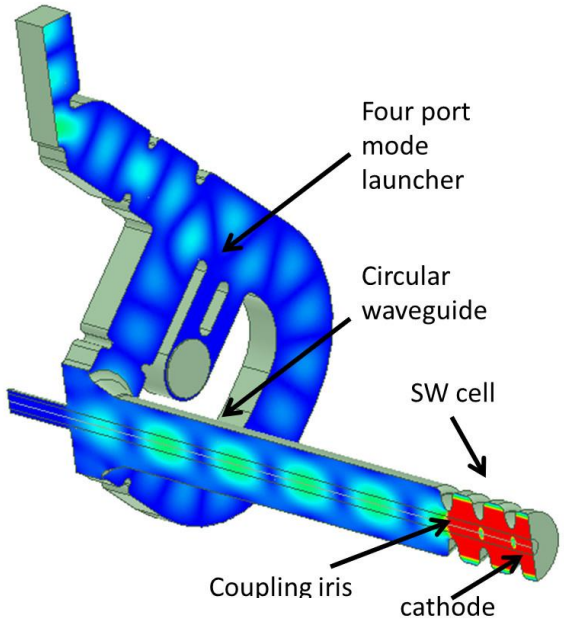
- **COMEB**: mechanical **construction SW gun**, mechanical **supports** and **movable screen with magnetic corrector**.

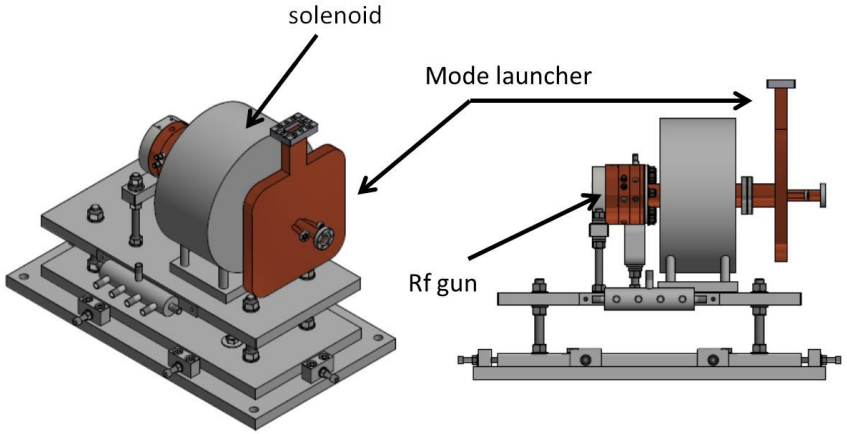
- **VDL: Machining** of the cups and couplers of the **TW gun**.

- **INFN and PSI**: A comprehensive study and optimization of the **beam dynamics** aspects, to fully exploit the devices potentialities, will be led by

SW GUN (INFN)

⇒ Powered with **short pulses** (300 ns) of few tens of MW to reduce the pulsed heating (~$\sqrt{\tau}$) and BDR (~τ^5);
⇒ **e.m. design** completed
⇒ **Mechanical design** in progress
⇒ Design compatible with **1 kHz rep. rate**;
⇒ **Cathode peak field (E_{cath})> 160 MV/m**
⇒ **4-port mode launcher (no pulse heating)**
⇒ (Commercial) **circulator is necessary**;





Parameter	value	
Frequency [GHz]	5.712	
$E_{cath}/\sqrt{P_{diss}}$ [MV/(m·MW$^{0.5}$)]	52	
Input power [MW]	18	23
Cathode field [MV/m]	160	180
Cathode type	copper	
Rep. rate [Hz]	1000	100
Quality factor	11800	
Filling time [ns]	164	
Coupling coeff.	3	
RF pulse length [ns]	300	
E_{surf}/E_{cath}	0.9	
Mod. Poy. Vect. [W/μm^2]	2.5	3.1
Pulsed heating [^{o}C]	<20	
Av.diss. Power [W]	2300	300

TW GUN (PSI)

- **Motivation:** exploring new designs of electron source at C-band frequency that could represent a future upgrade of the SwissFEL injector.

- **Approach:** higher electric field at cathode with shorter RF pulses
- **Performances:**

  Brightness up to a **factor 3-4** higher than the SwissFEL with gradient at cathode up to **200 MV/m**

- **Impact on SwissFEL:**

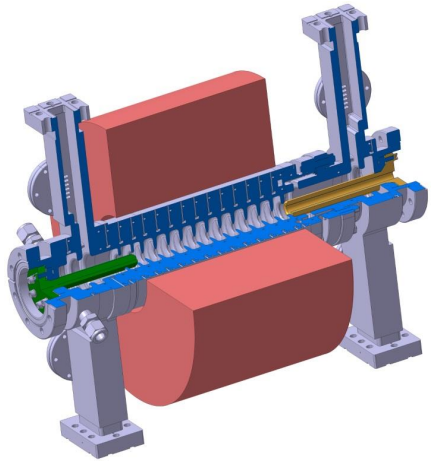
  Overall magnetic bunch compression relaxed along the linac→ **better stability and faster setup of the linac**

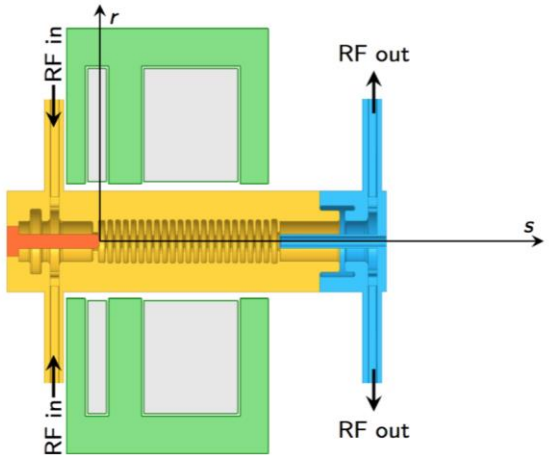
Parameter	Value	Unit
Frequency	5712	MHz
Phase advance	120	deg
Repetion rate	100	Hz
Group velocity	0.0079	
Q	10000	
R/Q	8268	W/m
Regular cell	10	
RF length	220	mm
Filling time	90	ns

Gradient at cathode	135	MV/m
Gun output energy	12.7	MeV

Gradient at cathode	200	MV/m
Gun output energy	13.9	MeV

Courtesy P. Craievich

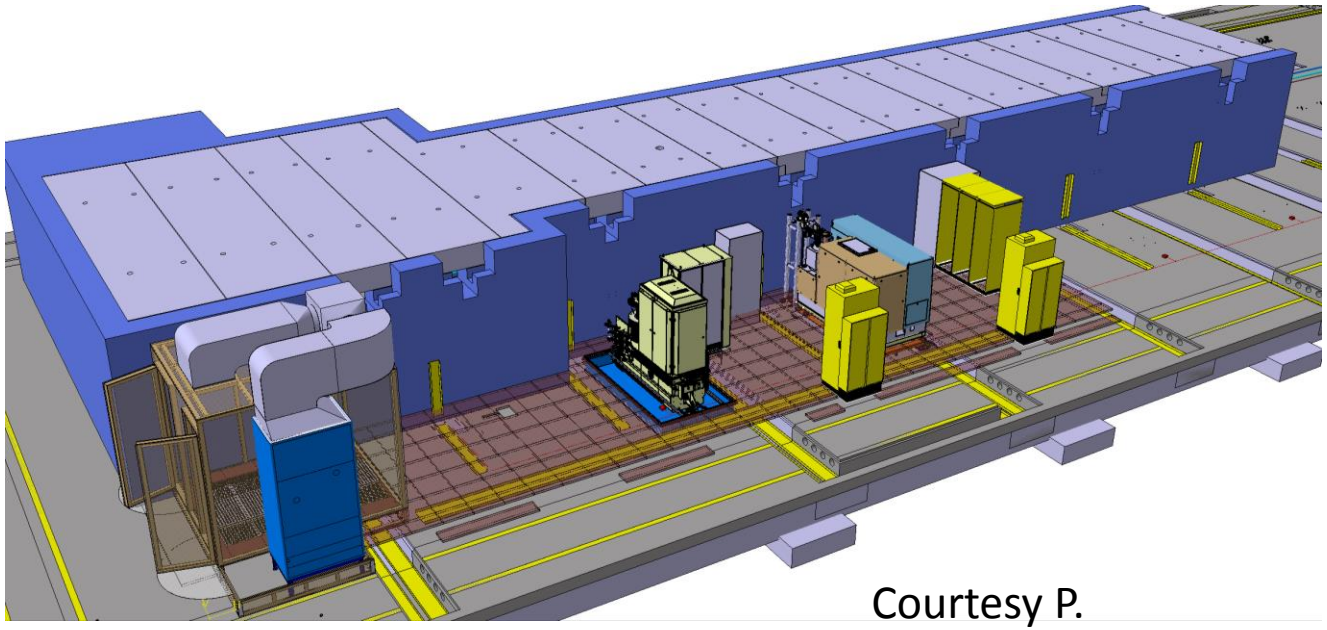




Reference: M. schaer et al. PR AB 19, 072001, 2016

RF test facility @PSI for SwissFEL upgrade

Bunker already used for the SwissFEL Injector Test Facility



Courtesy P. Craievich

Status:

- **HV klystron modulator is running** on C-band PSI loads (max power 50 MW)
- **Bunker**: document preparation to get permission, some modifications are needed

CONCLUSION Task 7.4

iFAST

⇒ Design, realization and high power test of two different C-band (@5.712 GHz) RF electron guns
⇒ SW GUN (INFN+COMEB) TW GUN (PSI+VDL)
⇒ High power test @PSI
⇒ Beam dynamics simulations to exploit the device potentialities

THANK YOU FOR YOUR ATTENTION

⇒ The availability of a new state-of-the-art C band electron injector would bring benefits to a large accelerator user community: FEL radiation sources, Thomson/Compton photon sources and plasma based accelerators
⇒ Compact dimensions, high flux and cost effectiveness expand the potentiality of the device towards industrial applications and small-scale research facilities.

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